How good will EUV masks need to be to meet LER requirements?

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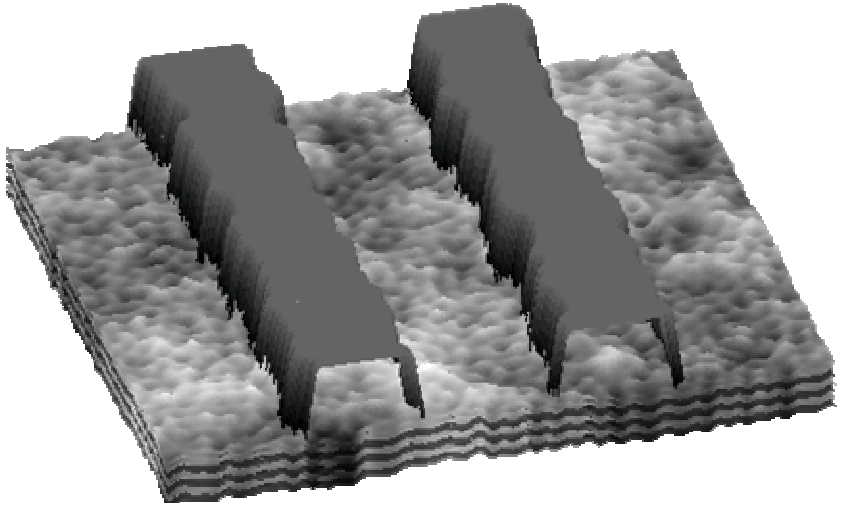


Outline

Problem

Evidence

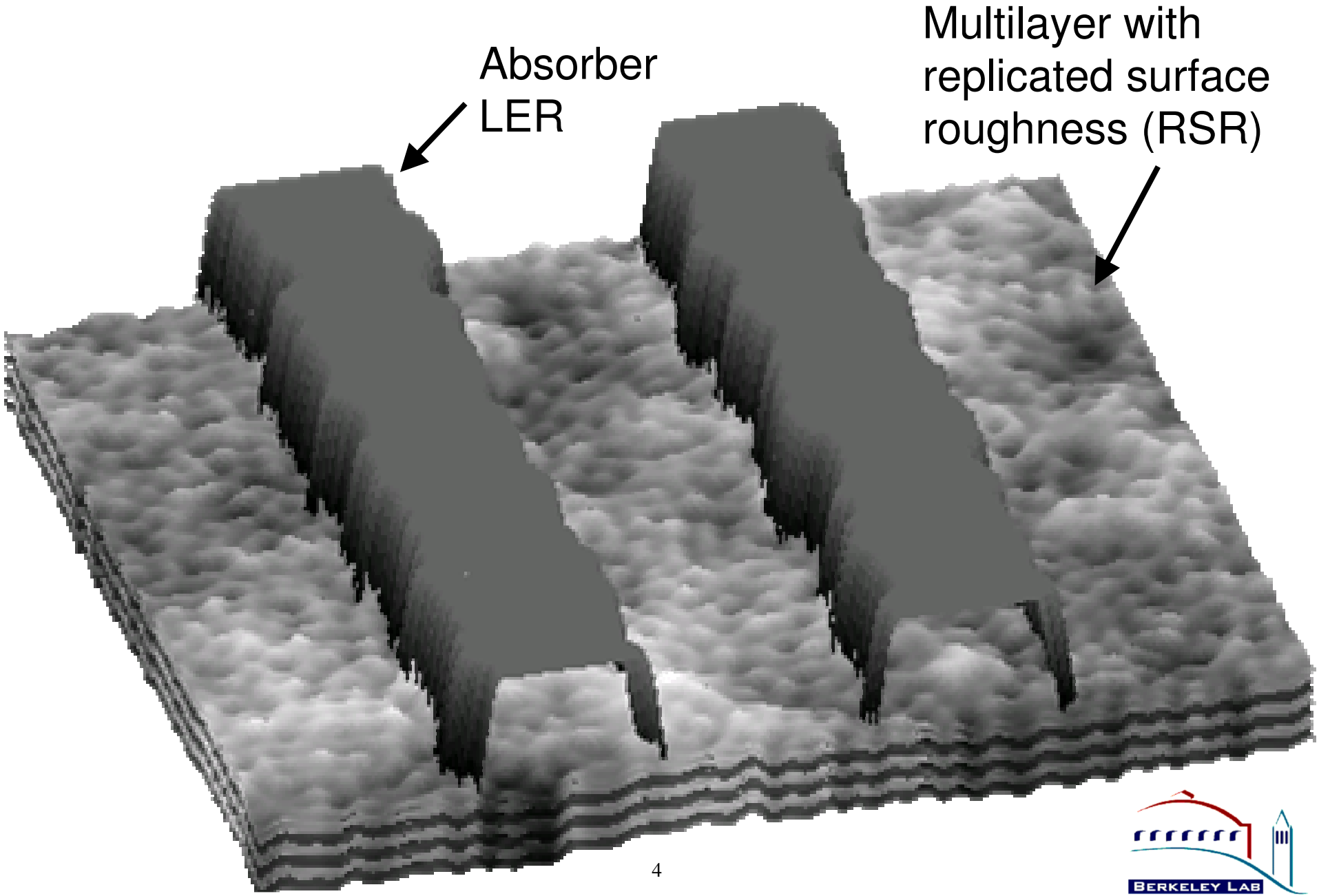
Implications

Complications

Summary

The Problem

Mask sources of LER



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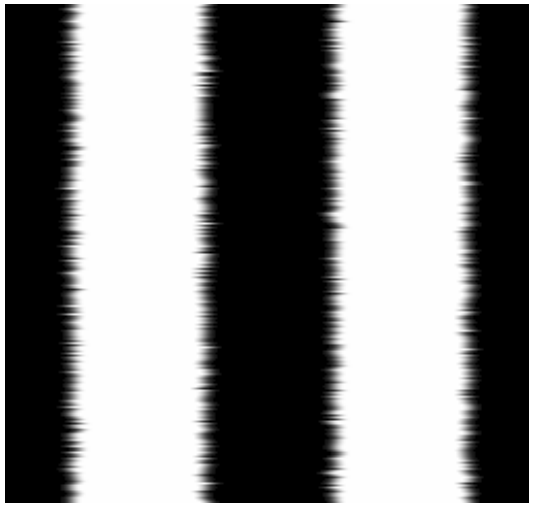
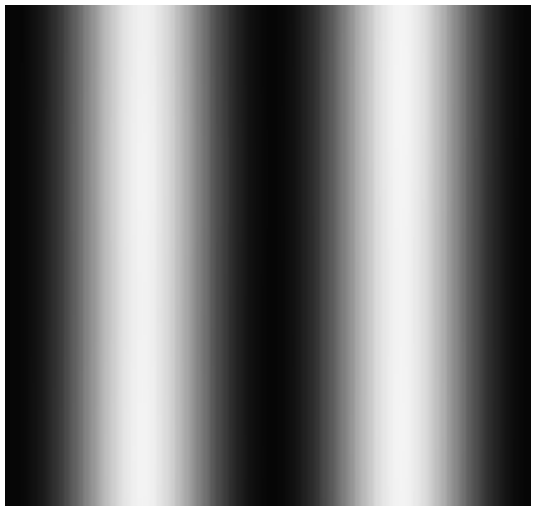
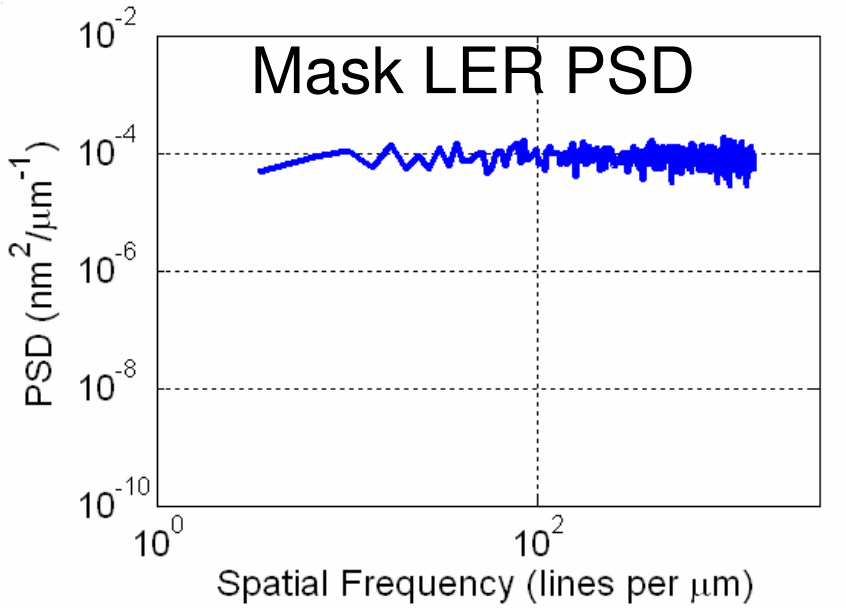
Imaging demagnifies and filters mask LER

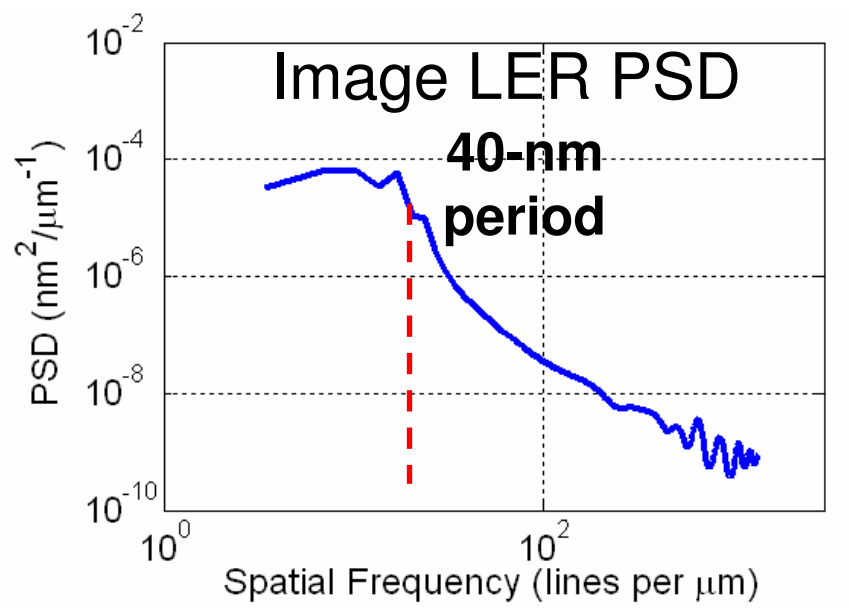


0.32 NA

$\sigma = 0.5$







Appl. Opt. **42**, 3390-3397 (2003)

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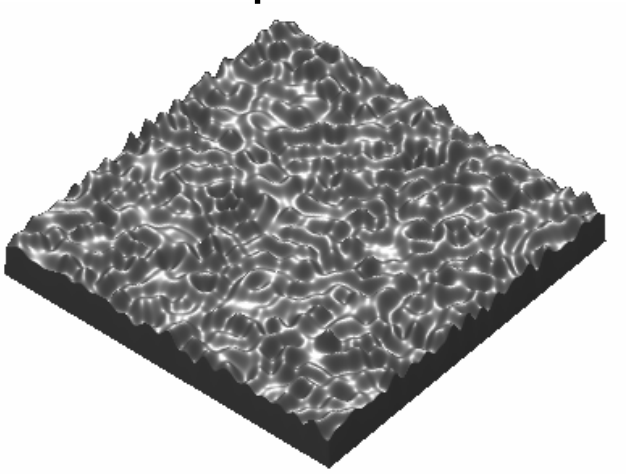
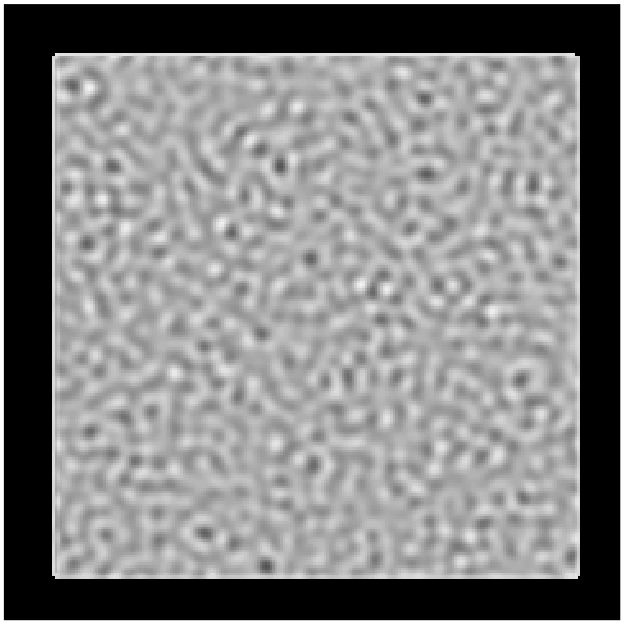
Imaging transforms replicated surface (phase) roughness to intensity speckle

230 pm RSR



50-nm defocus
$\sigma = 0.3$

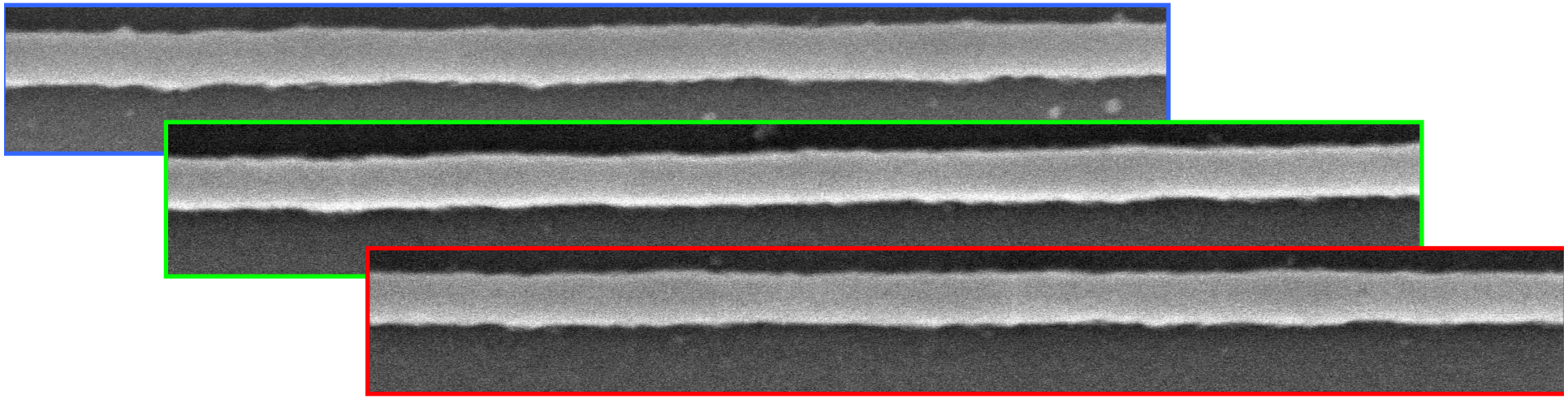
Contrast = 9%



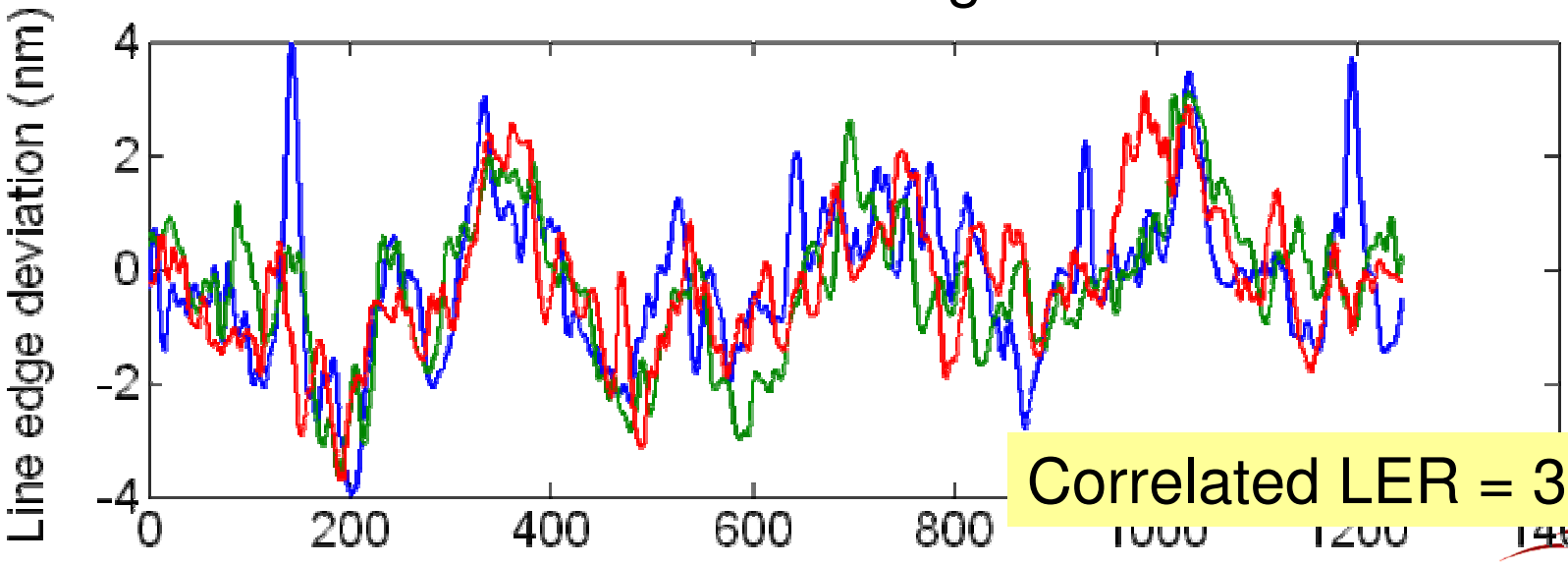
See Goldberg et al, Tuesday 12:20PM for experimental demonstration

Experimental evidence

Exposure-to-exposure correlation observed



LER ~ 4.3 nm Average correlation = 61%



Correlated LER = 3.4 nm

Correlated LER = (Full LER)*sqrt(correlation)

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Good agreement between measured correlated LER and modeled mask-induced LER

Configuration	Measured correlated LER (nm)	Modeled mask-induced LER (nm)
Mono, F=100 nm	3.4 ± 0.2	3.0
Ann, F=100 nm	2.7 ± 0.3	2.5
Ann, F=0 nm	2.0 ± 0.3	1.4

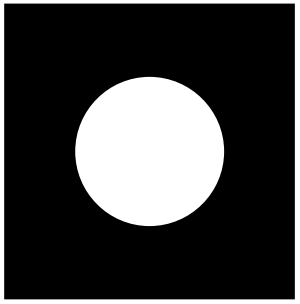
* Correlated LER = (Full LER)*sqrt(correlation)
Uncertainty based on limited extent of correlation measurement relative to bandwidth

Implications

Modeling assumptions

22-nm HP

0.32 NA

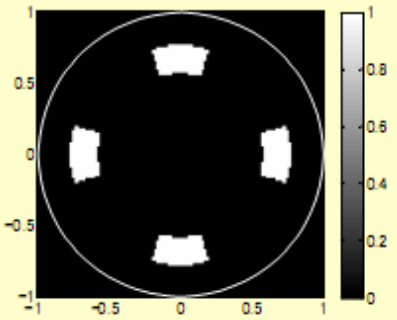


Disk $\sigma = 0.5$

Ideal optic assumed in all cases

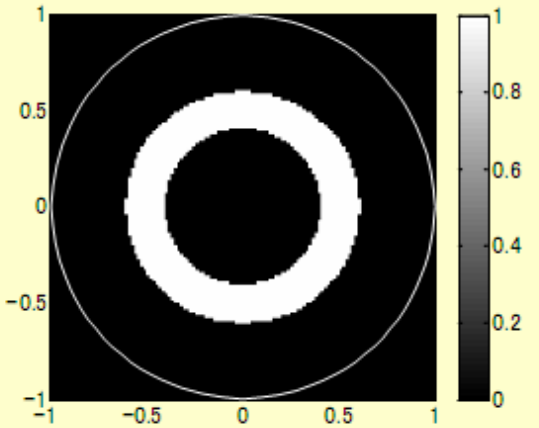
16-nm HP

0.32 NA



Cross-pole
$\sigma_{out} = 0.76$
$\sigma_{in} = 0.57$

0.42 NA



2/3 Annular
$\sigma_{out} = 0.6$

From Canon's SPIE AL09 presentation

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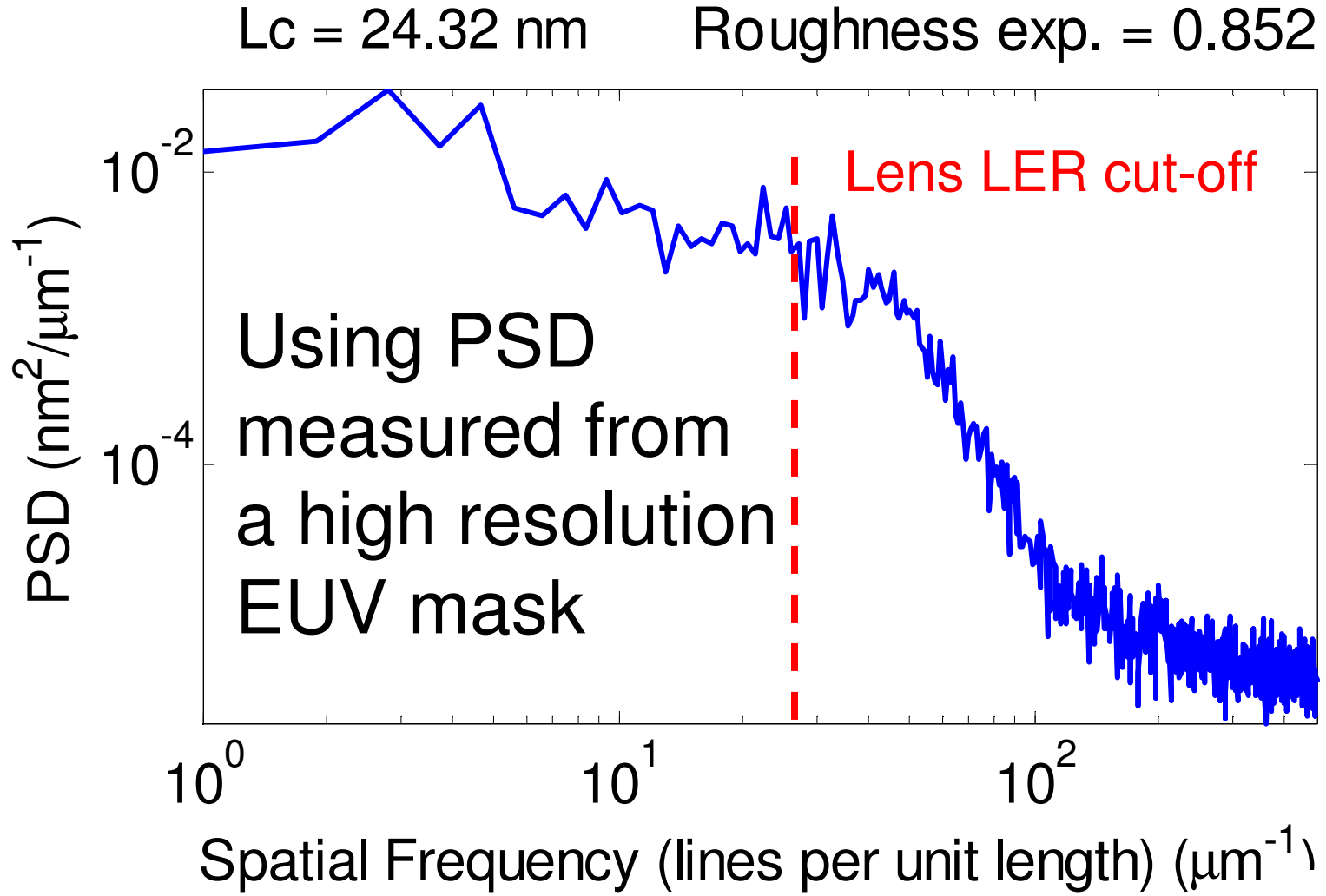
Error budget allocation assumptions

Half pitch (nm)	22	16
Total image plane LWR (nm)[1]	1.8	1.3
Mask LWR contribution (nm)[2]	0.7	0.5
Allowable DOF reduction (%)[3]	30	30

[1] 8% of CD (from ITRS)
[2] 10% contribution to total in quadrature
[3] Reduction from the NILS = 1 DOF

Mask absorber LER coupling depends on mask LER PSD



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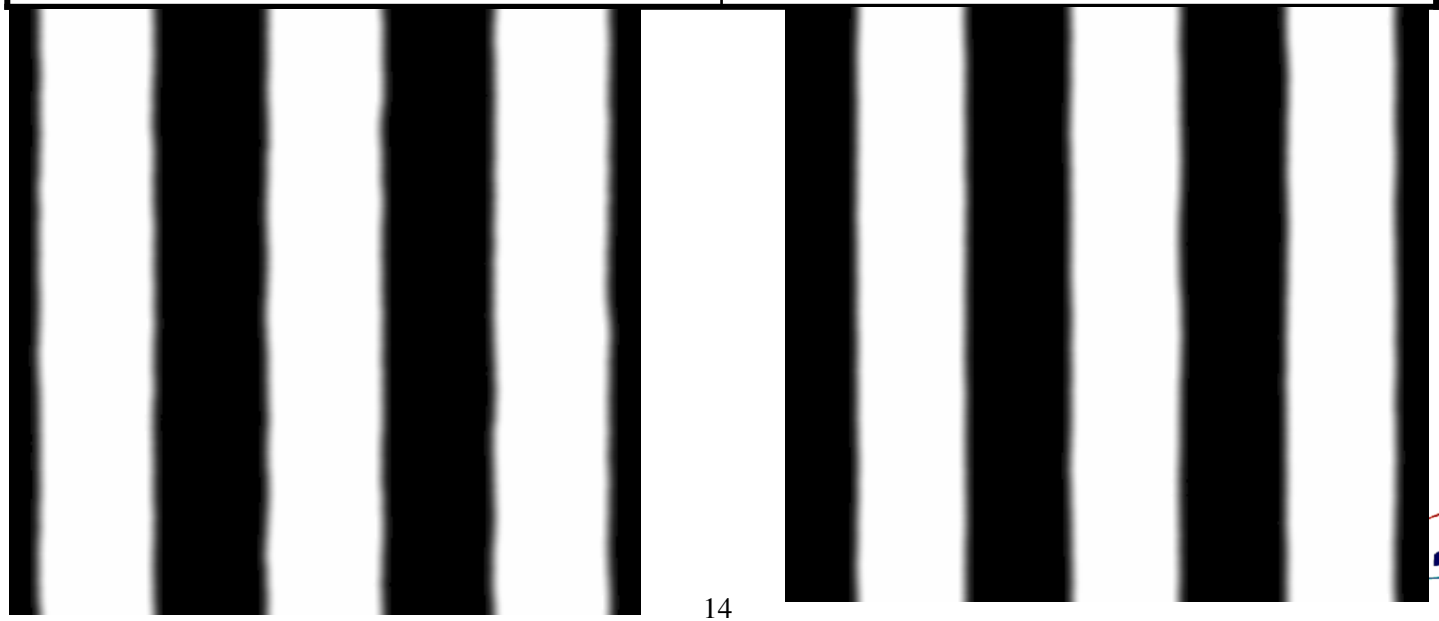
Mask LER magnitude based on 2008 ITRS

Half pitch (nm)	3σ LWR (nm)
22	2.0
16	1.4



22 nm

16 nm

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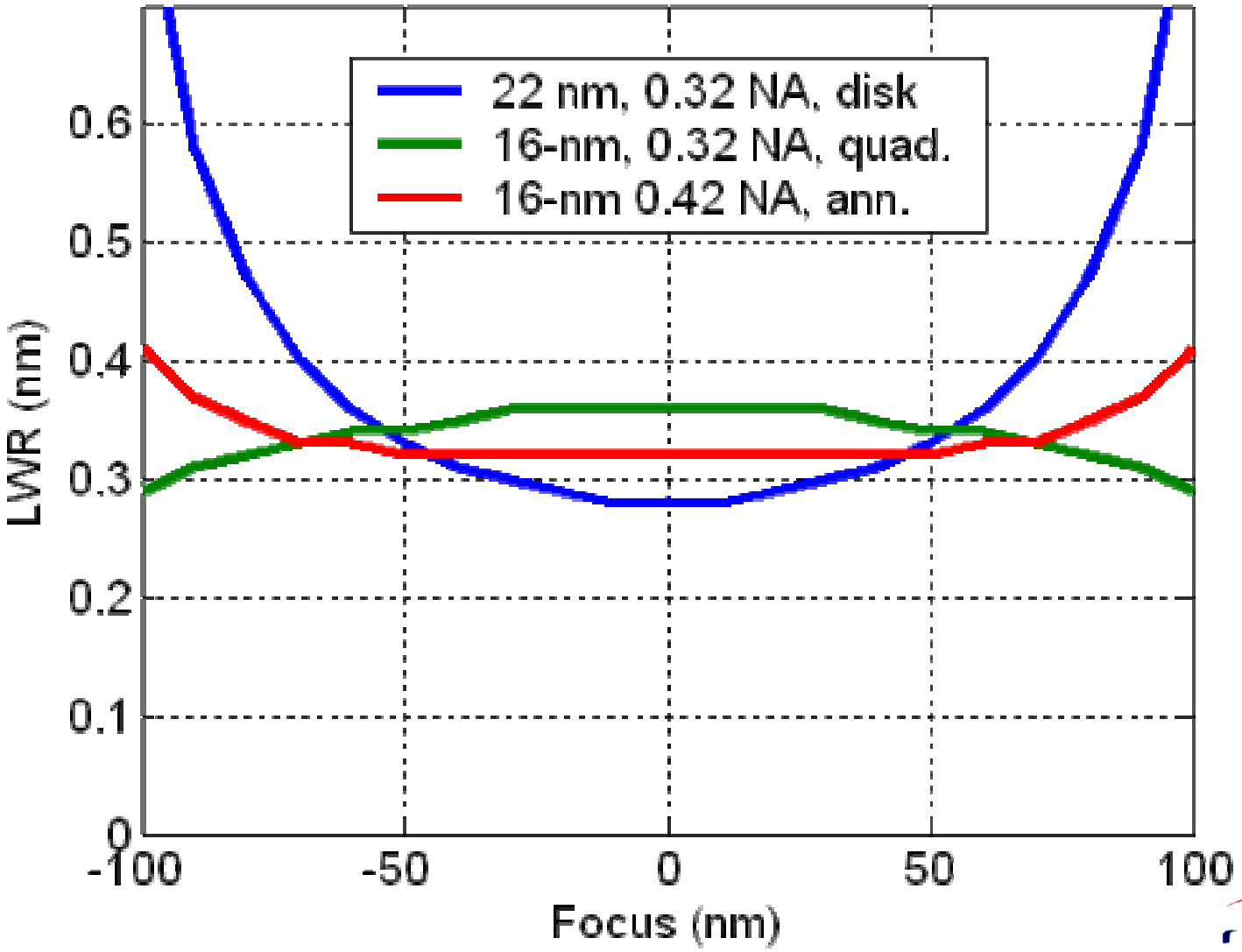
Modeled image plane LWR resulting from ITRS spec mask LER



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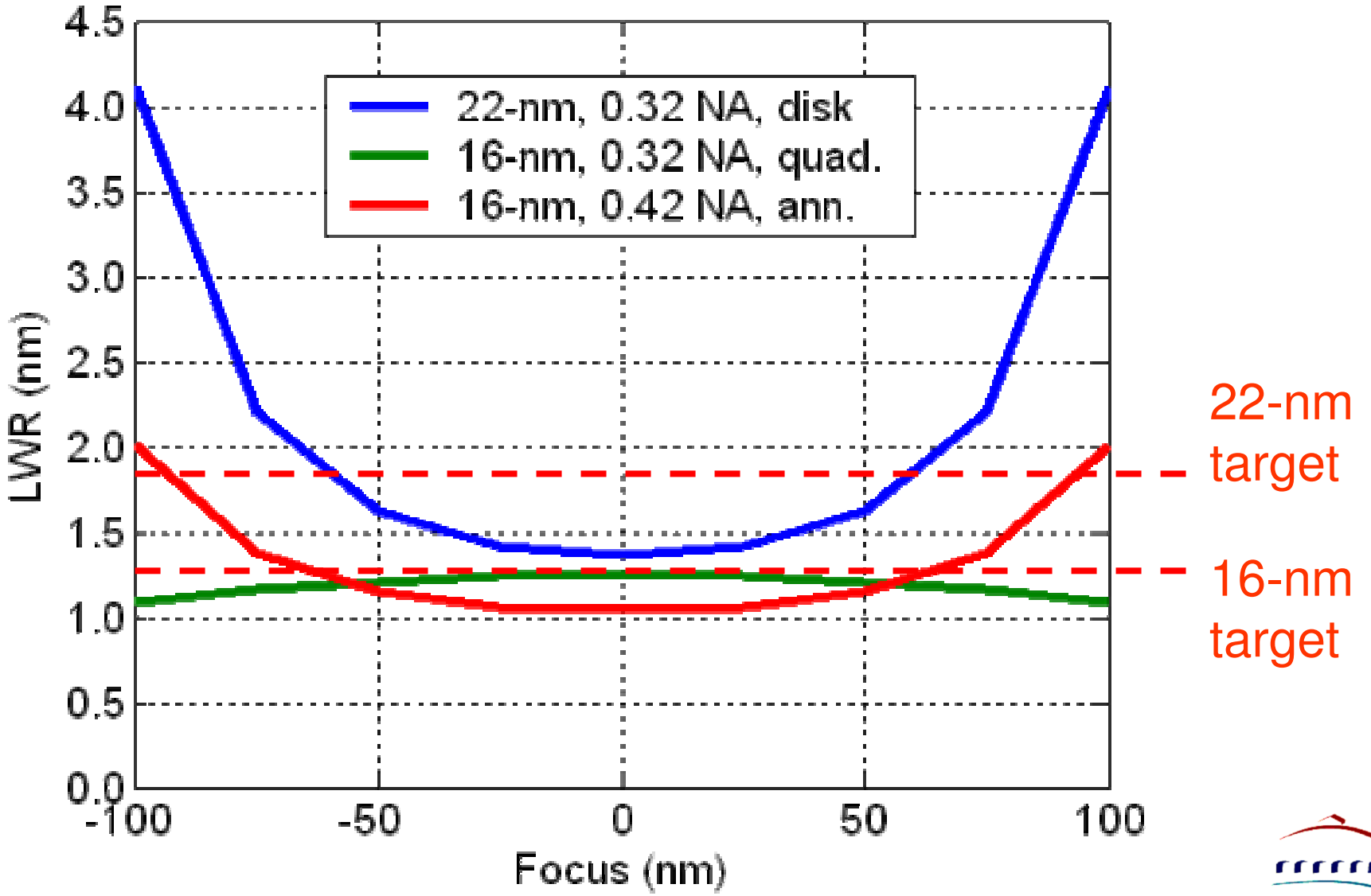
What if we use expected mask LWR values?

Half pitch (nm)	3σ LWR (nm)
22	8.0
16	6.0

What if we use expected mask LWR values?



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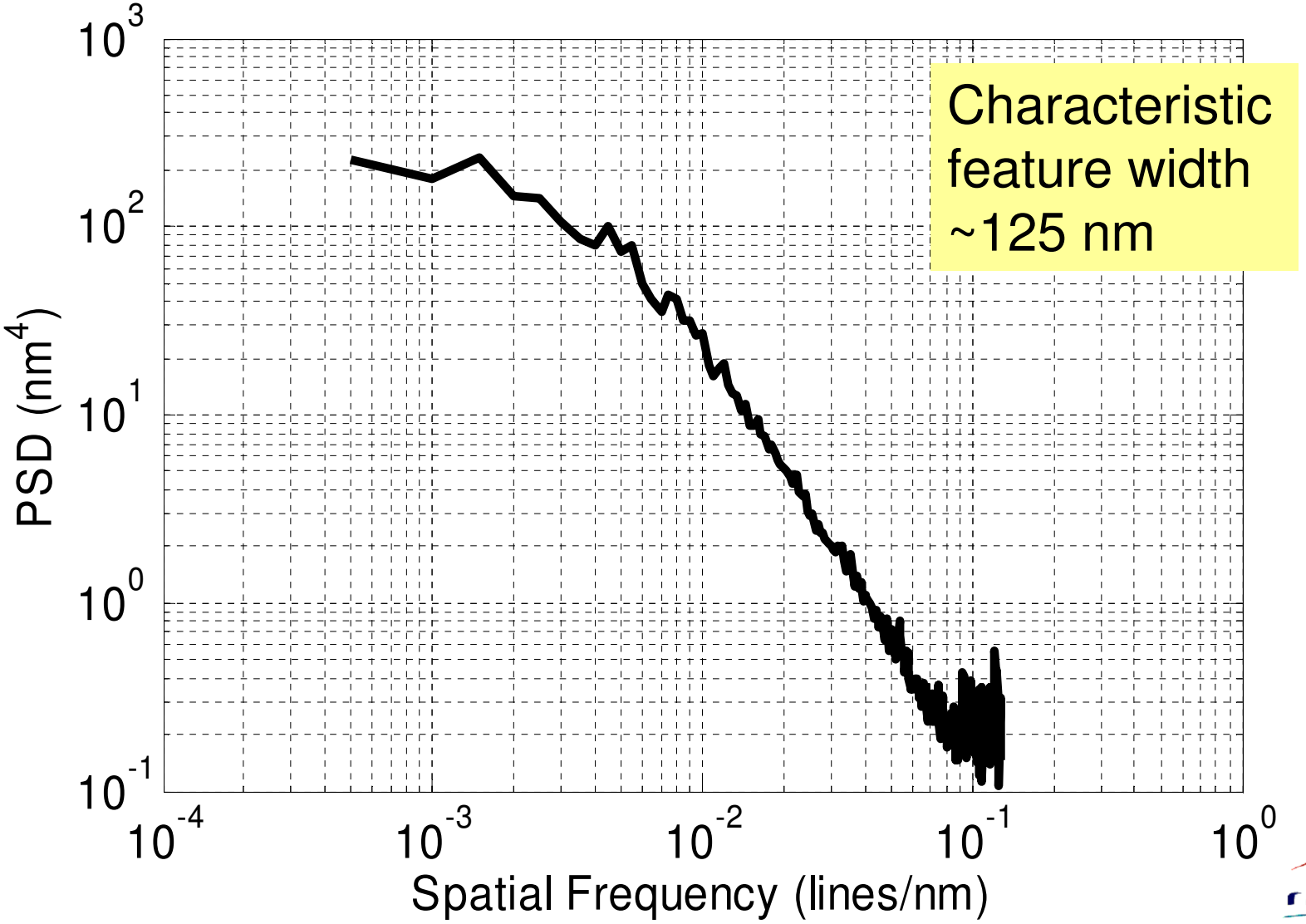
Multilayer replicated roughness is generally low frequency



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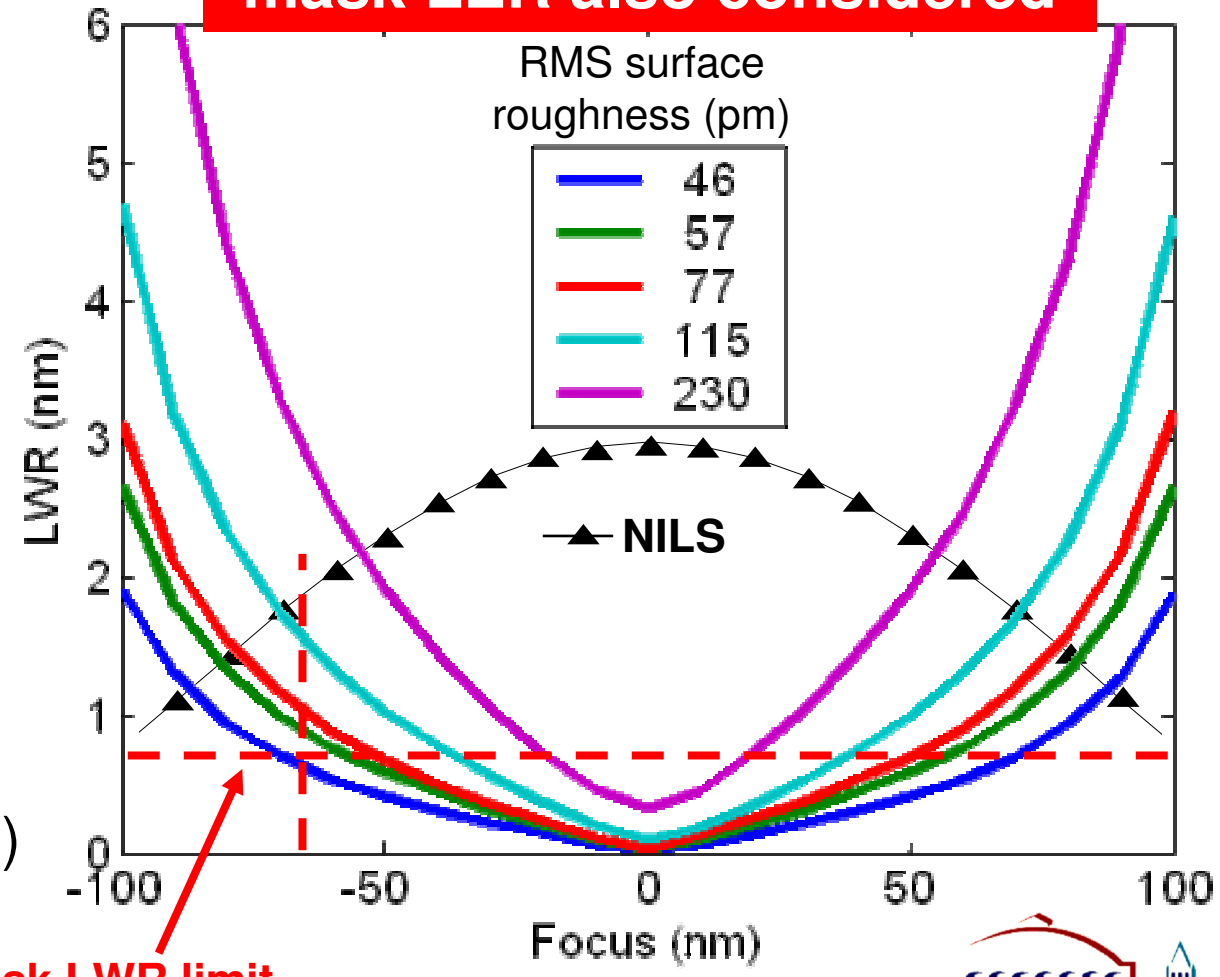
Roughness sensitivity @ 22-nm HP

Litho Parameters
- 0.32 NA
- Disk σ = 0.5
- 22-nm half pitch
- Ideal optic

LWR Limits
- Total: 1.8 nm (8% of CD)
- Mask: 0.7 nm (10% impact on total)

DOF Requirement
- 130 nm (70% of NILS=1 DOF)

46-pm RMS surface roughness requirement if mask LER also considered



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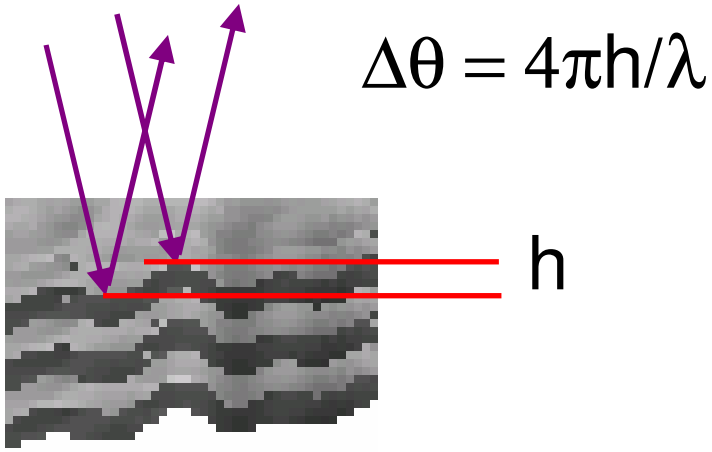
Mask roughness limits summary

Configuration	RSR limit (pm)	RSR limit with mask LER (pm)
22-nm, 0.32 NA	46	46
16-nm, 0.32 NA	77	77
16-nm, 0.42 NA	77	57

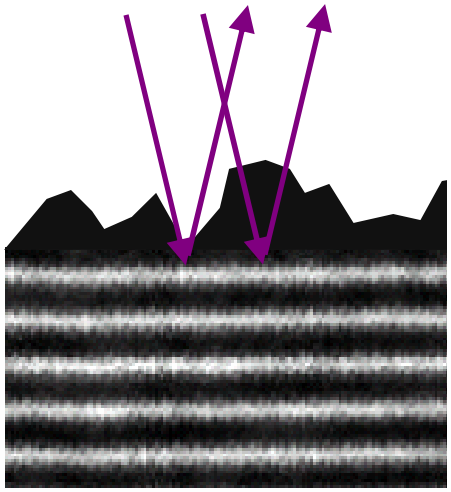
Rough Capping Layer

With capping layer roughness, phase shift is no longer geometric, but refractive

RSR is geometric effect



Impact of capping layer roughness depends on capping material refractive index



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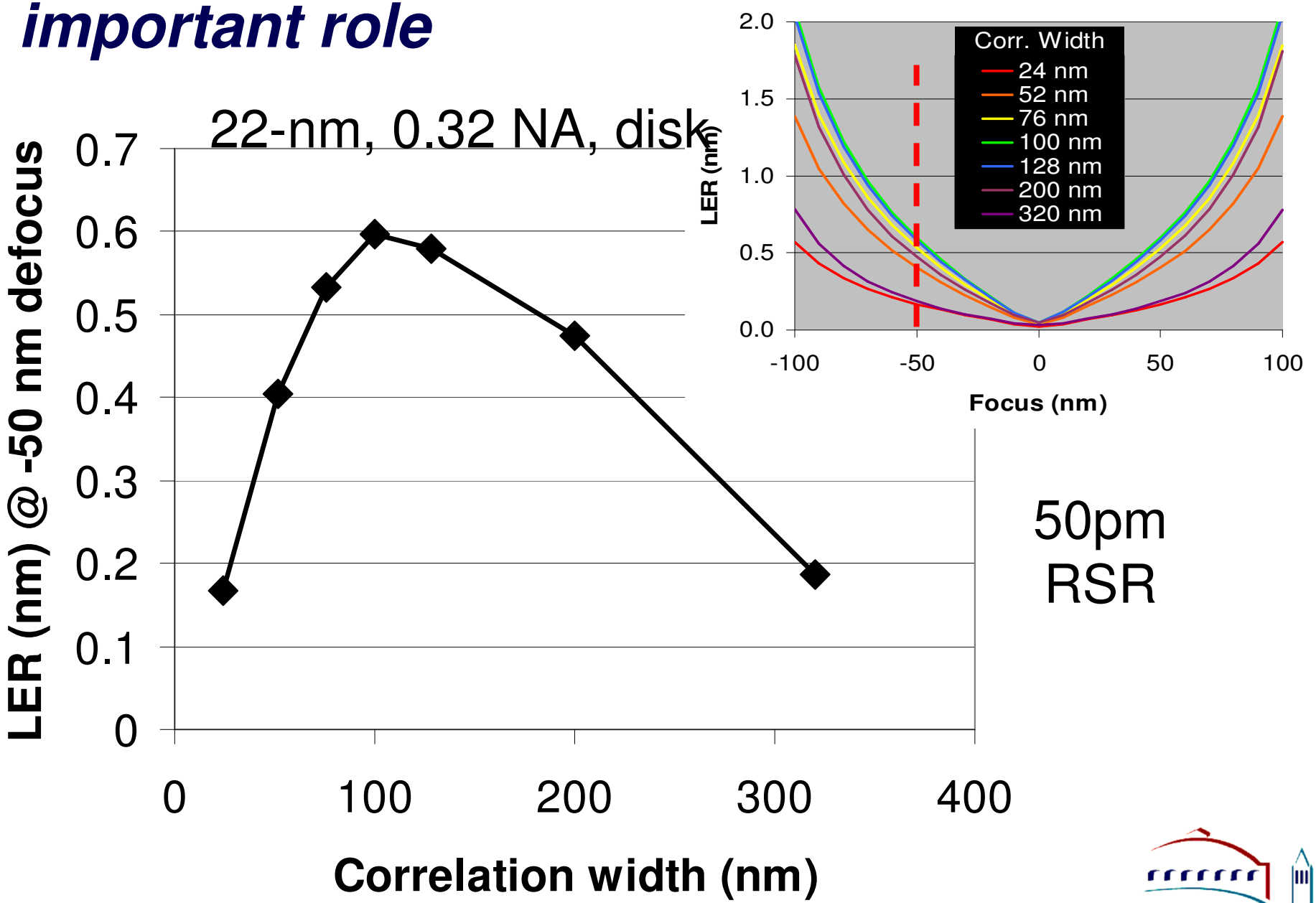
Sensitivity to capping layer roughness highly dependent on material and much lower than RSR

Capping Material	Double Pass Phase Shift per nm of material	Roughness Equivalent to 50 pm RSR*
Si	0.002°	730 nm
Ru	6°	0.44 nm
C	2°	1.25 nm

Roughness correlation width plays important role



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Summary

- Replicated mask substrate roughness leads to image plane LER
- Current LER requirements indicate replicated roughness limits near 50 pm
- Predicted 50-pm RSR limit relies on achieving stringent absorber LER specs

Acknowledgements

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